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**Core paper – XI Plant bio chemistry**

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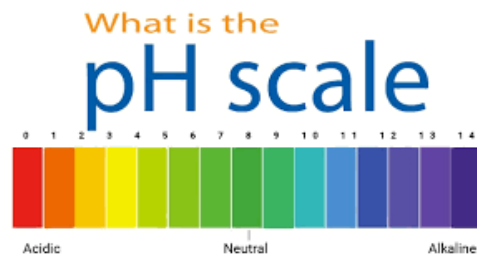
**UNIT –II**

# pH

The pH is defined as the negative  $\log_{10}$  of the hydrogen ion concentration expressed in mol/L. A negative logarithmic scale is used because the numbers are all less than 1, and vary over a wide range. Since the pH is the negative logarithm of the hydrogen ion concentration, low pH numbers, e.g. pH 6.2, indicate relatively high hydrogen ion concentrations, i.e. an acidic solution. High pH numbers, e.g. pH 7.8, represent lower hydrogen ion concentrations, i.e. alkaline solutions. Because the pH scale is logarithmic to the base 10, a 1-unit change in pH represents a 10-fold change in hydrogen ion concentration.

## Significance of pH

- **In Agriculture:** By determining the pH of the soil. We can find whether it is acidic or alkaline. This helps in deciding the type of fertilizer to be used and the types of crops to sown.
- **In Biological process:** By knowing pH we can adjust the medium of biological processes like fermentation, enzyme hydrolysis, sterilization etc.
- **In corrosion research:** By measuring the pH of sea-water, the effect of alkaline sea-water on the material used for building ships and submarines is studied



## pH scale

in 1909 S.P.L Sorenson, a Danish biochemist devised a scale known as pH to represents the  $H^+$  ion concentration of an aqueous solution. The pH value of any solution is a number that simply represents the acidity and basicity of the solution. The pH value of any solution is numerically equal to the logarithm of the inverse of the hydrogen ion ( $H^+$ ) concentration. Hence, the pH solution is referred to as the negative logarithm of hydrogen ion.

**pH** stands for '**potential of Hydrogen**' which measures the acidity or alkalinity of water-soluble substances. It is measured with a logarithmic scale known as pH.

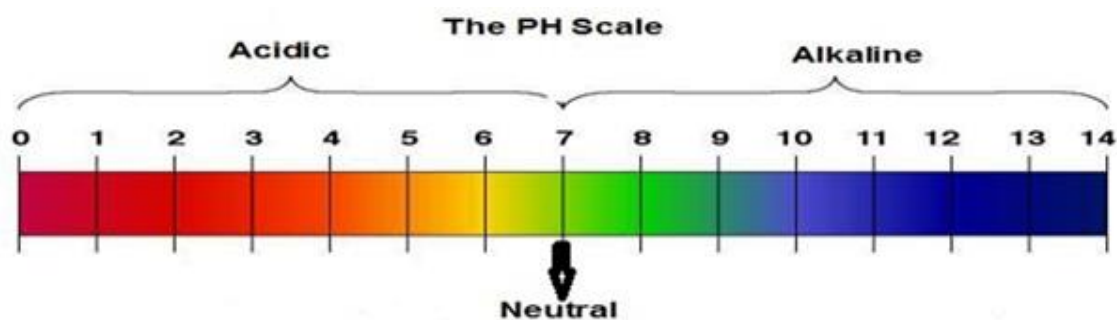
An acid is a substance that donates **hydrogen** ions that is when in a solution there are more hydrogen ions than hydroxide ions, the solution will be acidic. A base is a substance that accepts hydrogen ions that is when in a solution there are more hydroxide ions than hydrogen ions, the solution will be alkaline. The pH value of any solution is numerically equal to the logarithm of the inverse of the hydrogen ion (H<sup>+</sup>) concentration. Hence, the pH solution is referred to as the negative logarithm of hydrogen ion.

$$\text{pH} = -\log [\text{H}^+]$$

$$= \log 1/ [\text{H}^+]$$

### The basic concept of pH value

- *pH of Neutral Solution (Pure Water):* pH of water is 7. Whenever the pH of a solution is 7, it will be a neutral solution. Such a solution will have no effect on any litmus solution or any other indicator.
- *pH of an Acidic Solution:* All the acidic solutions have a pH of less than 7. So, whenever a solution has a pH less than 7, it will be acidic in nature and it will turn blue litmus into the red as well as methyl orange pink and phenolphthalein colourless.
- *pH of a basic solution:* All the alkaline solution has a pH of more than 7. So, whenever a solution has more than 7 values then it will be basic in nature and it will turn red litmus to blue, methyl orange to yellow and phenolphthalein to pink.
- 



<b>pH values of the common substance from our daily life</b>			
<b>Solution</b>	<b>pH</b>	<b>Solution</b>	<b>pH</b>
Conic <i>HCl</i>	0	Saliva (before meal)	7.4
Oil <i>HCl</i>	1.0	Saliva (after meal)	5.8
Gastric Juice	1.4	Blood	7.4
Lemon Juice	2.5	Eggs	7.8
Vinegar	4.0	Toothpaste	8.0
Tomato Juice	4.1	Baking Soda Solution	8.5
Coffee	5.0	Washing Soda Solution	9.0
Soft Drink	6.0	Milk of Magnesia	10.5
Milk	6.5	Household Ammonia	11.6
Pure Water	7.0	Dilute Sodium Hydroxide	13.0
		Concentrated Sodium Hydroxide	14

### **Universal Indicator of colour at pH scale**

It is a mixture of different indicators (or dyes) which gives different colours at different pH values of the entire pH scale. The colour produced by universal indicators at various pH values are given in the table below:

<b>Colour</b>	<b>pH</b>	<b>Colour</b>	<b>pH</b>
Dark Red	0	Greenish Yellow	8
Red	1	Blue	9
Red	2	Navy Blue	10
Orange Red	3	Purple	11
Orange	4	Dark Purple	12
Orange Yellow	5	Violet	13
Greenish Yellow	6	Violet	14
Green	7		

## Henderson–Hasselbalch equation

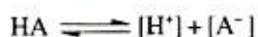
It can be used to estimate the pH of a buffer solution. The numerical value of the acid dissociation constant,  $K_a$ , of the acid is known or assumed. The pH is calculated for given values of the concentrations of the acid, HA and of a salt, MA, of its conjugate base,  $A^-$ ; for example, the solution may contain acetic acid and sodium acetate.

## History

In 1908, Lawrence Joseph Henderson derived an equation to calculate the pH of a buffer solution. In 1917, Karl Albert Hasselbalch re-expressed that formula in logarithmic terms, resulting in the Henderson–Hasselbalch equation.

The dissociation of weak acid in equilibrium.

**Let us consider HA, a weak acid that ionizes as follows:**



$$\therefore K_a = \frac{[H^+][A^-]}{[HA]} \quad [\because K_a = \text{Dissociation constant}]$$

$$\therefore [H^+] = \frac{K_a \times [HA]}{[A^-]}$$

$$\therefore \log[H^+] = \log K_a + \log \frac{[HA]}{[A^-]} \quad [\text{Taking log on both sides}]$$

$$\therefore -\log[H^+] = -\log K_a - \log \frac{[HA]}{[A^-]} \quad [\text{Changing sign on both sides}]$$

$$\therefore \text{pH} = \text{p}K_a + \log \frac{[A^-]}{[HA]} \quad [\because -\log[H^+] = \text{pH and } -\log K_a = \text{p}K_a]$$

$$\therefore \text{pH} = \text{p}K_a + \log$$

The above equation is known as Henderson-Hasselbalch equation.

### **Application:**

The equation can be used to determine the pH of blood.

### **Importance:**

1. With the help of this equation an individual is judged of his/her normal condition when concentration of  $[\text{BHCO}_3] : [\text{H}_2\text{CO}_3] = 20: 1$

Or,  $[\text{B}_2\text{HPO}_4] : [\text{BH}_2\text{PO}_4] = 4 : 1$  at his/her of blood is 7.4.

If the above-mentioned ratios are altered the individuals are considered as suffering from acidosis or alkalosis. They are treated with medicine according to the conditions (acidosis or alkalosis) to cure them to lead a normal life.

## **Application**

The Henderson–Hasselbalch equation can be used to calculate the pH of a solution containing the acid and one of its salts, that is, of a buffer solution. With bases, if the value of an equilibrium constant is known in the form of a base association constant,  $K_b$  the dissociation constant of the conjugate acid may be calculated from

$$pK_a + pK_b = pK_w$$

where  $K_w$  is the self-dissociation constant of water.  $pK_w$  has a value of approximately 14 at 25 °C.

If the "free acid" concentration,  $[\text{HA}]$ , can be taken to be equal to the analytical concentration of the acid,  $T_{\text{AH}}$  (sometimes denoted as  $C_{\text{AH}}$ ) an approximation is possible, which is widely used in biochemistry; it is valid for very dilute solutions.

The effect of this approximation is to introduce an error in the calculated pH, which becomes significant at low pH and high acid concentration. With bases the error becomes significant at high pH and high base concentration.

## **Isoelectric point**

The **isoelectric point** (**pI**, **pH(I)**, **IEP**), is the pH at which a molecule carries no net electrical charge or is electrically neutral in the statistical mean. The standard nomenclature to represent the isoelectric point is pH(I). However, pI is also used. The net charge on the molecule is affected

by pH of its surrounding environment and can become more positively or negatively charged due to the gain or loss, respectively, of protons ( $H^+$ ).

Surfaces naturally charge to form a double layer. In the common case when the surface charge-determining ions are  $H^+/OH^-$ , the net surface charge is affected by the pH of the liquid in which the solid is submerged.

The pI value can affect the solubility of a molecule at a given pH. Such molecules have minimum solubility in water or salt solutions at the pH that corresponds to their **pI** and often precipitate out of solution. Biological amphoteric molecules such as proteins contain both acidic and basic functional groups. Amino acids that make up proteins may be positive, negative, neutral, or polar in nature, and together give a protein its overall charge. At a pH below their pI, proteins carry a net positive charge; above their pI they carry a net negative charge. Proteins can, thus, be separated by net charge in a polyacrylamide gel using either preparative gel electrophoresis, which uses a constant pH to separate proteins or isoelectric focusing, which uses a pH gradient to separate proteins. Isoelectric focusing is also the first step in 2-D gel polyacrylamide gel electrophoresis.

## **Buffers**

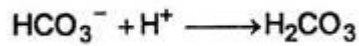
A Buffer Solution or a buffer is defined as a solution whose pH does not change when small amount of an acid or base is added in it. It is used as a means of keeping pH at a nearly constant value in a wide variety of chemical applications. Many life forms thrive only in a relatively small pH range so they utilize a buffer solution to maintain a constant pH. In nature, the bicarbonate buffering system is used to regulate the pH of blood. The solution of Sodium Acetate and Acetic acid is an example of an effective buffer solution. The solution in which buffer solution is accommodated that works like an extremely slow acid.

A buffer is a chemical substance that helps maintain a relatively constant pH in a solution, even in the face of addition of acids or bases. Buffering is important in living systems as a means of maintaining a fairly constant internal environment, also known as homeostasis. Small molecules such as bicarbonate and phosphate provide buffering capacity as do other substances, such as hemoglobin and other proteins.

## **Buffer System:**

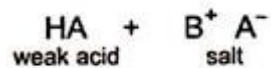
A buffer system has the property of resisting pH changes despite additions of acid or base. A buffer is a mixture of an acid that does not ionize completely in water and its corresponding base—for example, carbonic acid ( $H_2CO_3$ ) and sodium bicarbonate ( $NaHCO_3$ ).

If acid is added to this buffer, the added H<sup>+</sup> ions combine with bicarbonate ions to produce more carbonic acid, using up some of the H<sup>+</sup> ions (the Na<sup>+</sup> ions do not participate in this reaction).



If base is added, some of the carbonic acid ionizes to produce bicarbonate ions and more H<sup>+</sup>, which counteracts some of the pH. In this way, the buffer minimizes the effects of the added acid or base on the pH. Buffers illustrate the reversibility of chemical reactions, the addition of acid drives the reaction in one direction, whereas addition of base drives the chemical reaction in the other direction.

An adequate buffer system can be obtained from a weak acid mixed with the salt from that acid and a strong base. For example,



where B<sup>+</sup> = the cation of a strong base e.g., Na<sup>+</sup>; A<sup>-</sup> = anion from weak acid

This corresponds to a partially neutralized solution of weak acid (HA → H<sup>+</sup> + A<sup>-</sup>) with some reasonable proportion of the acid converted to the anion. Its pH will be higher than the pH of the weak acid alone.

The pH of a buffer solution is determined not on the absolute concentrations of buffer constituents but on their ratio, i.e., on the ratio of the amount of salt to weak acid as stated in the Henderson Hasselbalch equation:

$$\text{pH} = \text{pKa} + \log [\text{salt}]/[\text{acid}]$$

Where Ka is the dissociation constant of the acid and pKa is the pH at which the acid is half neutralized and equal amounts of acid and ion (salt) are present. This equation is applicable to all the buffer systems. The buffer capacity, measured as the ability of the solution to minimize changes in pH due to addition of base, is strongest near the midpoint of a titration, when [A<sup>-</sup>] = [HA] and pH = pKa.

The most important examples of biological buffer systems are as follows:

### **Bicarbonate Buffer**

The maintenance of blood pH is regulated via the bicarbonate buffer. This system consists of carbonic acid and bicarbonate ions. When the blood pH drops into the acidic range, this buffer



acts to form carbon dioxide gas. The lungs expel this gas out of the body during the process of respiration. During alkaline conditions, this buffer brings pH back to neutral by causing excretion of the bicarbonate ions through the urine.

### **Phosphate Buffer**

The phosphate buffer system acts in a manner similar to the bicarbonate buffer, but has much stronger action. The internal environment of all cells contains this buffer comprising hydrogen phosphate ions and dihydrogen phosphate ions. Under conditions when excess hydrogen enters the cell, it reacts with the hydrogen phosphate ions, which accepts them. Under alkaline conditions, the dihydrogen phosphate ions accept the excess hydroxide ions that enter the cell.

### **Protein Buffer**

Proteins consist of amino acids held together by peptide bonds. The amino acids possess an amino group and a carboxylic acid group. At physiological pH, the carboxylic acid exists as the carboxylate ion ( $\text{COO}^-$ ) with a negative charge and the amino group exists as the  $\text{NH}_3^+$  ion. When the pH becomes acidic, the carboxyl group takes up excess hydrogen ions to return back to the carboxylic acid form. If the blood pH becomes alkaline, there is a release of a proton from the  $\text{NH}_3^+$  ion, which takes the  $\text{NH}_2$  form.

### **Hemoglobin Buffer**

The respiratory pigment present in blood, hemoglobin, also has buffering action within tissues. It has an ability to bind with either protons or oxygen at a given point of time. Binding of one releases the other. In hemoglobin, the binding of protons occurs in the globin portion whereas oxygen binding occurs at the iron of the heme portion. At the time of exercise, protons are generated in excess. Hemoglobin helps in the buffering action by binding these protons, and

### **Importance of Buffer System**

Buffer mixtures are very important in living organisms and the mineral world. An example of a natural buffer is the blood of mammals. It always contains free carbonic acid and sodium carbonate. Therefore, the pH of blood is always maintained at 7.4.

The buffering action of soils is very important in agriculture, because plants absorb artificial fertilizers from the soil to change the pH in solutions that they extract from the soil in an unfavourable direction. An imbalance in the buffering action of soil is detrimental to useful micro-organisms living in it.

Buffer solutions are very important in the treatment of domestic sewage, because the microorganisms which mineralize their organic matter thrive better in a neutral medium. A shift

towards acidity or alkalinity inhibits the vital processes in the microbes, thus adversely affecting the working of sewage treatment plants.

Buffers play an important role in the chemical treatment of water to separate it from suspended matter of coagulation. The higher the buffer capacity of the treated water, the more efficient its purification with a hydrolyzing coagulant. The buffer capacity of neutral water accounts for its neutralising power.

Buffers are widely used in volumetric analysis. For example, an ammonium buffer ( $\text{NH}_4\text{OH} + \text{NH}_4\text{Cl}$ ) is used to determine Ca and Mg ions in water (trilonometric method). Buffer mixtures are used to determine the pH of solutions colorimetrically and potentiometrically.

In cellular physiology, buffers are an important way for the cell to maintain constant or smoothly changing conditions. Since cellular metabolism is constantly producing and consuming protons, the pH of the cell in the absence of buffers would change rapidly between low and high levels.

### **Energy Currency of the Cell**

Plants, obtain their energy from the sunlight, and animals get their energy by feeding on these plants. Energy acts as a source of fuel.

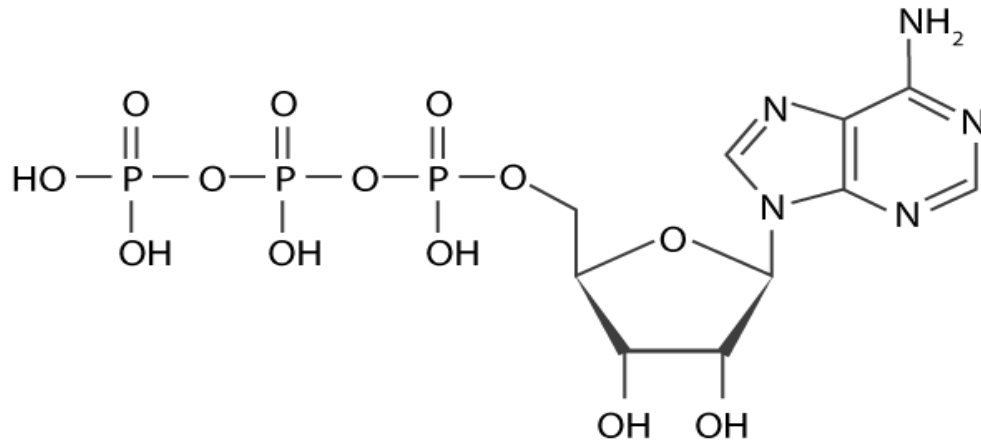
ATP – Adenosine triphosphate is called the energy currency of the cell.

It is the organic compound composed of the phosphate groups, adenine, and the sugar ribose. These molecules provide energy for various biochemical processes in the body. Therefore, it is called “Energy Currency of the Cell”. These ATP molecules are synthesized by Mitochondria, therefore it is called powerhouse of the cell.

The ATP molecule was discovered in the year 1929 by German chemist Karl Lohmann. Later in the year 1948, Scottish biochemist Alexander Todd was the first person to synthesized the ATP molecule.

ATP – the energy-carrying molecules are found in the cells of all living things. These organic molecules function by capturing the chemical energy obtained from the digested food molecules and are later released for different cellular processes.

## Structure of ATP Molecule



ATP – Adenosine triphosphate is a nucleotide, which is mainly composed of the molecule adenosine and three phosphate groups. It is soluble in water and has a high energy content, which is primarily due to the presence of two phosphoanhydride bonds connected to the three phosphate groups.

The triphosphate tail of ATP is the actual power source which the cell taps. The available energy is contained in the bonds between the phosphates and is released when they are broken or split into molecules. This occurs through the addition of a water molecule (hydrolysis). Usually, only the outer phosphate group is removed from ATP to yield energy; when this occurs, ATP – Adenosine triphosphate is converted into ADP – adenosine diphosphate, it is the form of the nucleotide having only two phosphates.

ATP molecules are largely composed of three essential components.

- The pentose sugar molecule i.e. ribose sugar.
- Nitrogen base- Adenine, attached to the first carbon of this sugar molecule.
- The three phosphate groups which are attached in a chain to the 5th carbon of the pentose sugar. The phosphoryl groups, starting with the group closest to the ribose sugar, are referred to as the alpha, beta, and gamma phosphates. These phosphates play an important role in the activity of ATP.

### How is Energy Produced by the ATP molecules?

The three phosphate groups present in this ATP molecule are called high energy bonds as they are involved in the liberation of a huge amount of energy when they are broken. This molecule provides energy for various life processes without which life cannot exist.

It is used by various enzymes and structural proteins in cellular processes like biosynthetic reactions, cell divisions, etc. This “energy currency of the cell” is produced during **cellular respiration** where a digested simple molecule of food is utilized.

Once after the energy is produced by the ATP molecules, they are stored in its bonds which are later utilized by the cells by breaking the bonds whenever required

### **Functions of ATP**

The ATP is used for various cellular functions, including transportation of different molecules across cell membranes. A significant role of ATP apart from energy production includes: synthesizing the multi-thousand types of macromolecules that the cell requires for their survival. ATP molecule is also used as a switch to control chemical reactions and to send messages.

### **Importance of ATP Molecule in Metabolism**

1. These ATP molecules can be recycled after every reaction.
2. ATP molecule provides energy for both the exergonic and endergonic processes.
3. It is the only energy, which can be directly used for different metabolic process. Other forms of chemical energy need to be converted into ATP before they can be used.
4. It plays an important role in the Metabolism – A life-sustaining chemical reactions including cellular division, fermentation, photosynthesis, photophosphorylation, aerobic respiration, protein synthesis, exocytosis, endocytosis and motility.

### **Laws of thermodynamics**

The **laws of thermodynamics** define a group of physical quantities, such as temperature, energy, and entropy, that characterize thermodynamic systems in thermodynamic equilibrium. The laws also use various parameters for thermodynamic processes, such as thermodynamic work and heat, and establish relationships between them. They state empirical facts that form a basis of precluding the possibility of certain phenomena, such as perpetual motion. In addition to their use in thermodynamics, they are important fundamental laws of physics in general, and are applicable in other natural sciences.

Traditionally, thermodynamics has recognized three fundamental laws, simply named by an ordinal identification, the first law, the second law, and the third law. more fundamental statement was later labelled as the zeroth law, after the first three laws had been established.

The zeroth law of thermodynamics defines thermal equilibrium and forms a basis for the definition of temperature: If two systems are each in thermal equilibrium with a third system, then they are in thermal equilibrium with each other.

The first law of thermodynamics states that, when energy passes into or out of a system (as work, heat, or matter), the system's internal energy changes in accord with the law of conservation of energy.

The second law of thermodynamics states that in a natural thermodynamic process, the sum of the entropies of the interacting thermodynamic systems never decreases. Another form of the statement is that heat does not spontaneously pass from a colder body to a warmer body.

The third law of thermodynamics states that a system's entropy approaches a constant value as the temperature approaches absolute zero. With the exception of non-crystalline solids (glasses) the entropy of a system at absolute zero is typically close to zero.

### **Zeroth law**

The zeroth law of thermodynamics provides for the foundation of temperature as an empirical parameter in thermodynamic systems and establishes the transitive relation between the temperatures of multiple bodies in thermal equilibrium. The law may be stated in the following form:

If two systems are both in thermal equilibrium with a third system, then they are in thermal equilibrium with each other.

Though this version of the law is one of the most commonly stated versions, it is only one of a diversity of statements that are labeled as "the zeroth law". Some statements go further, so as to supply the important physical fact that temperature is one-dimensional and that one can conceptually arrange bodies in a real number sequence from colder to hotter.

These concepts of temperature and of thermal equilibrium are fundamental to thermodynamics and were clearly stated in the nineteenth century. The name 'zeroth law' was invented by Ralph H. Fowler in the 1930s, long after the first, second, and third laws were widely recognized. The law allows the definition of temperature in a non-circular way without reference to entropy, its conjugate variable. Such a temperature definition is said to be 'empirical'.

### **First law**

The first law of thermodynamics is a version of the law of conservation of energy, adapted for thermodynamic processes. In general, the conservation law states that the total energy of an isolated system is constant; energy can be transformed from one form to another, but can be neither created nor destroyed.

In a closed system (i.e. there is no transfer of matter into or out of the system), the first law states that the change in internal energy of the system ( $\Delta U_{\text{system}}$ ) is equal to the difference between the heat supplied to the system ( $Q$ ) and the work ( $W$ ) done *by* the system on its surroundings. (Note, an alternate sign convention, not used in this article, is to define  $W$  as the work done *on* the system by its surroundings):

energy of the new system,  $U_{\text{system}}$ , will be equal to the sum of the internal energies of the two initial systems,  $U_1$  and  $U_2$ :

## Second law

The second law of thermodynamics indicates the irreversibility of natural processes, and, in many cases, the tendency of natural processes to lead towards spatial homogeneity of matter and energy, and especially of temperature. It can be formulated in a variety of interesting and important ways. One of the simplest is the Clausius statement, that heat does not spontaneously pass from a colder to a hotter body.

It implies the existence of a quantity called the entropy of a thermodynamic system. In terms of this quantity it implies that

When two initially isolated systems in separate but nearby regions of space, each in thermodynamic equilibrium with itself but not necessarily with each other, are then allowed to interact, they will eventually reach a mutual thermodynamic equilibrium. The sum of the entropies of the initially isolated systems is less than or equal to the total entropy of the final combination. Equality occurs just when the two original systems have all their respective intensive variables (temperature, pressure) equal; then the final system also has the same values.

The second law is applicable to a wide variety of processes, both reversible and irreversible. According to the second law, in a reversible heat transfer, an element of heat transferred,  $\delta Q$ , is the product of the temperature ( $T$ ), both of the system and of the sources or destination of the heat, with the increment ( $dS$ ) of the system's conjugate variable, its entropy ( $S$ ):

While reversible processes are a useful and convenient theoretical limiting case, all natural processes are irreversible. A prime example of this irreversibility is the transfer of heat by conduction or radiation. It was known long before the discovery of the notion of entropy that when two bodies, initially of different temperatures, come into direct thermal connection, then heat immediately and spontaneously flows from the hotter body to the colder one.

Entropy may also be viewed as a physical measure concerning the microscopic details of the motion and configuration of a system, when only the macroscopic states are known. Such details are often referred to as *disorder* on a microscopic or molecular scale, and less often as *dispersal*

*of energy*. For two given macroscopically specified states of a system, there is a mathematically defined quantity called the 'difference of information entropy between them'. This defines how much additional microscopic physical information is needed to specify one of the macroscopically specified states, given the macroscopic specification of the other – often a conveniently chosen reference state which may be presupposed to exist rather than explicitly stated. A final condition of a natural process always contains microscopically specifiable effects which are not fully and exactly predictable from the macroscopic specification of the initial condition of the process. This is why entropy increases in natural processes – the increase tells how much extra microscopic information is needed to distinguish the initial macroscopically specified state from the final macroscopically specified state. Equivalently, in a thermodynamic process, energy spreads.

### **Third law**

The third law of thermodynamics can be stated as:

A system's entropy approaches a constant value as its temperature approaches absolute zero.

a) Single possible configuration for a system at absolute zero, i.e., only one microstate is accessible. b) At temperatures greater than absolute zero, multiple microstates are accessible due to atomic vibration (exaggerated in the figure)

At zero temperature, the system must be in the state with the minimum thermal energy, the ground state. The constant value (not necessarily zero) of entropy at this point is called the residual entropy of the system. Note that, with the exception of non-crystalline solids (e.g. glasses) the residual entropy of a system is typically close to zero. However, it reaches zero only when the system has a unique ground state (i.e. the state with the minimum thermal energy has only one configuration, or microstate). Microstates are used here to describe the probability of a system being in a specific state, as each microstate is assumed to have the same probability of occurring, so macroscopic states with fewer microstates are less probable. In general, entropy is related to the number of possible microstates according to the Boltzmann principle:

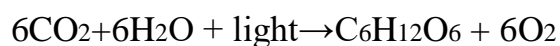
Where  $S$  is the entropy of the system,  $k_B$  Boltzmann's constant, and  $\Omega$  the number of microstates. At absolute zero there is only 1 microstate possible ( $\Omega=1$  as all the atoms are identical for a pure substance and as a result all orders are identical as there is only one combination) and  $\ln(1) = 0$ .

### **Free energy**

The **thermodynamic free energy** is a concept useful in the thermodynamics of chemical or thermal processes in engineering and science. The change in the free energy is the maximum amount of work that a thermodynamic system can perform in a process at constant temperature,

and its sign indicates whether a process is thermodynamically favorable or forbidden. Since free energy usually contains potential energy, it is not absolute but depends on the choice of a zero point. Therefore, only relative free energy values, or changes in free energy, are physically meaningful.

The free energy is a thermodynamic state function, like the internal energy, enthalpy, and entropy. The ultimate source of energy for all biological transformations is sunlight. Green plants, algae, and a few bacteria make use of the radiative energy in the visible wavelength range, from about 400 to 800 nm, for the synthesis of energy-rich organic compounds, such as glucose, from simple inorganic molecules, essentially water and carbon dioxide. Glucose is the prototype of food for higher organisms. The overall reaction of photosynthesis is represented by



(1)

The first important, and yet very complex, stage is the reduction of  $\text{NADP}^+$  and the phosphorylation of ADP to ATP with the release of molecular oxygen. In a subsequent chain of “dark reactions”, NADPH and ATP serve as energy sources for the reduction of  $\text{CO}_2$ .

## Energy transfer

### Photochemical Reaction

*“The photochemical reaction is none other than a chemical reaction that starts with light being absorbed as a form of energy”*. Temporary peak states would be triggered while the molecules absorb light and there would be physical and chemical property differences to a large extent from the real molecules.

The resultant chemical structures could be separated, modified, mixed among the similar or different molecules along with the transfer of hydrogen atoms, electronic charge to separate molecules, protons, and electrons. The peak states in comparison to the real ground states are stronger reductants and acids that are stronger.

The mechanism of a photo reaction should ideally include a detailed characterization of the primary events as outlined by the classification of photochemical reaction pathways. The quantum yields and hence the rate constants of all relevant photophysical and photochemical processes, in addition to the information about the structure and fate of any reactive intermediates, their lifetimes and reactivities.



## Photochemical Reaction in Photosynthesis

- Photosynthesis is the final property of the process that is one of the widely discussed topics in the world as it sustains the life on planet Earth.
- **Photosynthesis is a photochemical process** by which green plants, seaweeds, algae, and certain bacteria absorb solar energy and utilize it to convert the atmospheric carbon dioxide to carbohydrates in the presence of water.
- Using photosynthesis, plants would convert the sunlight energy into the chemical energy being stored and thereby form carbohydrates using water and carbon dioxide and releases oxygen as a by product of the reaction.
- Animal life is sustained with the aid of oxygen and carbohydrates.

## Reduction potential

**Redox potential** (also known as **oxidation / reduction potential**, '**ORP**', **pe**, **E<sub>0</sub>'**, or ) is a measure of the tendency of a chemical species to acquire electrons from or lose electrons to an electrode and thereby be reduced or oxidised respectively. Redox potential is measured in volts (V), or **millivolts** (mV). Each species has its own intrinsic redox potential; for example, the more positive the reduction potential (reduction potential is more often used due to general formalism in electrochemistry), the greater the species' affinity for electrons and tendency to be reduced. ORP can reflect the antimicrobial potential of the water.

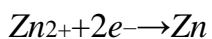
In a redox (reduction-oxidation) reaction, electrons are transferred from an electron donor (or electron "source") to an electron acceptor (or electron "sink"). The electron source becomes oxidized while the electron sink becomes reduced. The tendency for molecules to gain electrons is measured as the **reduction potential**. The opposite, *oxidation potential*, can also be used to discuss redox reactions. However, in contemporary practice, we use *reduction potential* values and refer to them as **redox potential (E<sup>o</sup>)** values. These values are related to thermodynamics and to the values of K and Gibbs free energy.

## Standard reduction potential

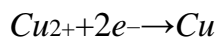
A redox reaction can be viewed as two reduction half-reactions. The **potential** of the reduction half-reaction is used to determine whether a redox reaction is favorable or not. Each reduction half reaction is written with the thing being reduced (electron "sink") on the left and the thing being oxidized (electron "source") on the right.

**For example the following redox reaction,**  
$$\text{Zn} + \text{Cu}^{2+} \rightarrow \text{Zn}^{2+} + \text{Cu}$$

can be viewed as two reduction half-reactions:



$$E^{\circ} = -0.7618^1 \text{ Volts}$$



$$E^{\circ} = +0.337^2 \text{ Volts}$$

Spontaneous reactions have a  $E^{\circ}_{\text{overall}} > 0$  according to the following equation:

$$E^{\circ}_{\text{overall}} = E^{\circ}_{\text{thing being reduced}} - E^{\circ}_{\text{thing being oxidized}}$$

In the equation above,  $E^{\circ}$  is the standard reduction potential; the reduction potential of the half-reaction at standard conditions.<sup>3</sup> Note that standard conditions are those at standard temperature and pressure, and at  $\text{pH} = 0$ .